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ABSTRACT
Microstructural characterization of soft-captured fragments of explosive-driven AerMet 100 alloy hollow cylinders is performed to understand dynamic deformation and localization phenomena. Examination of the fragments reveals the deformation is characterized by bands of localized shear strain and cracking. Fracture surface morphologies for the cylinders are ductile dimples, indicative of tensile or shear failure. Although both annealed and maraged AerMet 100 exhibit similar phenomenon, the width of the shear band in the annealed material is wider than in the maraged material, suggesting the former is more resistant to shear banding.

INTRODUCTION
Explosive-driven cylinders of AerMet 100 alloy were studied to understand dynamic deformation and fracture behavior (Chhabildas [2001]). Similar to earlier work by Mott and others (Mott [1947]; Taylor [1963]), that study focused on determining the statistics of cylinder fragmentation, *i.e.*, mass distributions. The work reported here discusses the metallurgical characterization to understand the role of microstructure in the dynamic deformation and fracture mechanisms that give rise to fragmentation.

PROCEDURES, RESULTS AND DISCUSSION
Annealed bar stock of 5-cm diameter AerMet 100 alloy was purchased from Carpenter Technology Corporation. The nominal composition in wt-% of the alloy is 0.24 C, 2.99 Cr, 11.05 Ni, 1.16 Mo, 13.32 Co and the balance is Fe. Sixteen hollow cylinders were produced with the dimensions of 5-cm outer diameter, 20-cm long and 3 mm wall-thickness.

Fifteen cylinders were given a maraging treatment, consisting of solution heat treatment, refrigeration, and age (Carpenter [1995]). After heat treatment, the HRc increased from 40 to 55. Fig. 1 shows the microstructure of AerMet 100 alloy in the annealed and maraged conditions. The annealed microstructure contains a lenticular martensitic structure. Randomly embedded in the matrix are approximately 1.5 μm sized spherical inclusions with areal density of ~ 40/mm^2 and mean spacing of ~ 1.7 mm. The inclusions are composed of rare earth elements, namely As, Ce and La.

After the maraging treatment, grain boundaries are homogeneously decorated with submicron-sized precipitates. The size and morphology of martensite appear relatively unaffected by the heat treatment.

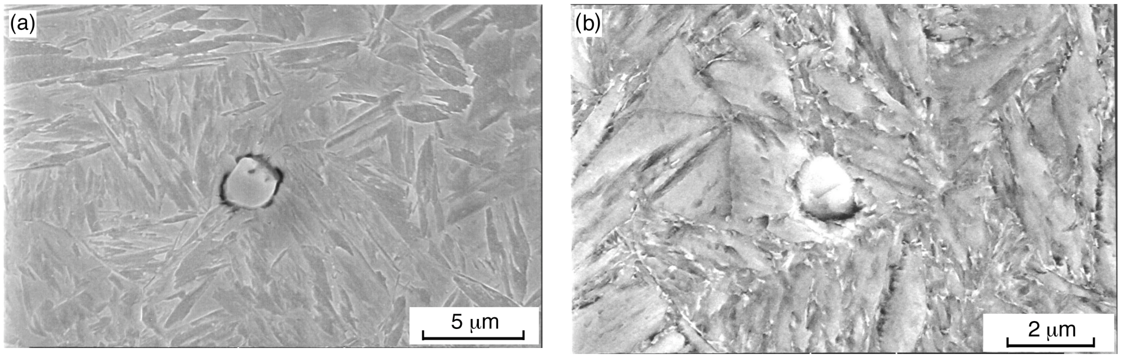

Figure 1. SEM micrographs of AerMet 100 alloy: a) annealed, and b) maraged.

Two cylinders, one annealed and the other maraged, with the different microstructures were exploded. The cylinders experienced strain rates on the order of $7x10^5$/s. In addition to real-time diagnostics, a fraction of the fragments were recovered in a manner designed to minimize additional damage.

Results from the experiments indicate a difference in the onset of cracking between the annealed and maraged cylinders. High-speed camera images show that the annealed (HRc 40) cylinder is more resistance to crack formation than the maraged (HRc 55) cylinder. The estimated diametric strain at cracking was 35-40% and 23-28%, respectively.

Fragments collected from both cylinders vary in shape from being high length-to-width aspect ratio to being roughly equiaxed. In addition, deformation and fracture features were similar between the annealed and maraged fragments. Figure 2a shows a representative fragment, in this case from the annealed cylinder. The surface of the fragments, corresponding to the original inner and outer surfaces of the cylinder, has a roughened appearance, caused by plastic deformation, and exhibits numerous surface cracks. Inclined fracture surfaces, where the fracture occurred along the length of the fragment, show teardrop shaped dimples. The ends of the fragments, where fracture occurred orthogonal to the length direction, show very fine, submicron sized equiaxed dimples. These fracture surface morphologies are those traditionally encountered in shear and normal tensile fractures, respectively.

A polished cross-section of the fragment (a surface orthogonal to the fragment length) reveals strain localization and apparent cracking within this localization. The orientation of the localization and cracking is in the through-thickness direction of the fragment, and is readily delineated by a region of highly sheared martensite neighbored by the nominal lenticular structure (Fig. 2b). Although the general appearance of the localization is similar between materials, the width of the localization in the annealed cylinder is approximately 5 μm. In the maraged cylinder the width of the localization is markedly smaller, on the order of 1 μm (Fig. 2c). The difference in the width of the localization band suggests the susceptibility of the harder, maraged material to strain localization is greater than for the softer, annealed material. In both materials the dynamic deformation and failure process of the AerMet 100 alloy cylinder appears to involve a combination of strain localization, crack nucleation and growth along the localization.

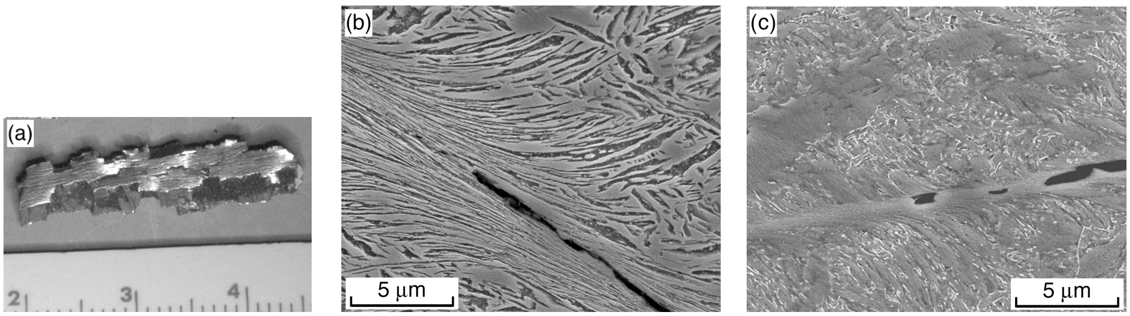

Fig. 2. Annealed AerMet 100 alloy fragment (a) and cross-sectional microstructures orthogonal to the fragment length; annealed (b) and maraged (c).

CONCLUSIONS

The microstructure of AerMet 100, as affected by heat-treatment, influences the deformation and fracture behavior of exploded cylinders. Annealed AerMet 100 cylinders fracture at 35-40% strain, whereas maraged AerMet 100 cylinders fracture at 23-28% strain. The shear bandwidth differs slightly between them; bandwidths of approximately 5 μm in the former and 1 μm in the latter. Fracture surface morphologies for the cylinders are similar, i.e., ductile dimple. Both heat-treated conditions show bands of highly localized strain in the recovered fragments. The relationship between the observed shear bandwidths and fracture strains is not fully understood.

ACKNOWLEDGMENTS

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